II. "On *Bacterium fœtidum*: an Organism associated with Profuse Sweating from the Soles of the Feet." By GEORGE THIN, M.D. Communicated by Professor HUXLEY, Sec. R.S. Received May 12, 1880.*

[PLATE 6.]

The feet of certain individuals are characterised by a peculiar powerful and fœtid odour. This odour, although it is usually believed to be connected with the sweat from the feet, is really connected with the moisture that soaks the soles of the stockings and the inside of the boots. The moisture, which comes from the skin of the soles, especially from that of the heels, has no offensive smell whilst it is exuding, but it rapidly acquires the characteristic odour when taken up by the stocking.

The fluid is not pure sweat, but is an admixture of sweat with serous exudation from the blood. This admixture occurs in persons whose feet sweat profusely, and who, from much standing or walking, acquire an erythematous or eczematous condition of the skin of the soles, the local erythema or eczema being favoured by the softening and macerating effect of the sweat on the epidermis. That the fluid is not sweat is shown by its reaction. In the case which furnished me with an opportunity for investigation the reaction with litmus paper applied to the wet heel was very faintly alkaline, the fluid in the stockings and on the inner surface of the sole of the boot being more decidedly, but still faintly, alkaline. At the same time the sweat on other parts of the body was acid.

When a small portion of the sole of the wet stocking was teased out in water, the drop of water was found to be swarming with minute spherical bodies, many of them being in pairs, fairly equal in size and refracting light uniformly. Clusters or colonies of them were lying on hollow parts of the cotton fibres. These bodies I shall in this paper call micrococci, implying by that term no more than that they were spherical, that they were found singly and in pairs, and that they were capable of development. No rod-shaped bacteria were found in the drop.

Having made more than one examination, and finding the micrococci always present, I inoculated with them a drop of pure vitreous humour, and placed it over a cell prepared in the usual manner. The cells were kept at a temperature of from 96° to 98° F., and within twenty-four hours appearances were observed which showed that the micrococci (or spores) were developing after the fashion in which the spores of the *Bacillus anthracis* are known to develop. In order to

* This paper records the results of one of a series of investigations on the parasites that infest the human skin, the expenses connected with which have been defrayed by the Scientific Grants Committee of the British Medical Association.

study more conveniently the different forms assumed by the organism when under cultivation, it was grown for successive generations in pure vitreous humour, contained in pure test glasses, and kept at 96° to 98° F.

The glasses, fitted with glass caps, and covered by a larger protecting glass, were placed on small glass squares and purified by being kept at a temperature over 300° F. for about two hours. The flasks for the vitreous humour were protected by carbolised cotton wool and similarly heated. The vitreous humour was obtained by collection from ox and sheep's eyes. It was squeezed through fine muslin, and introduced with proper precautions to a pure flask, which was then placed for half an hour in boiling water. All the apparatus used and the method of experimenting were modelled after those described by Mr. Lister in a paper on the lactic fermentation in the twenty-ninth volume of the "Transactions of the Pathological Society of London." It was ascertained that milk, vitreous humour, and turnip infusion, so prepared and protected by the carbolised cotton caps, kept free from organisms and retained their natural appearance and taste for periods extending over six weeks.

A second generation of the organism, which for convenience I may call *Bacterium fœtidum*, was obtained by placing a small piece of the wet stocking in one of the test-glasses, charged with pure vitreous humour. This and all the succeeding generations were cultivated at a temperature which varied between 94° and 98° F. The successive generations were obtained by inoculating pure vitreous humour, with requisite precautions.

In twenty-four hours the surface of the vitreous humour was always found covered with a delicate scum, which in forty-eight hours was compact and tolerably resistant.

In the scum of one day's growth and in the fluid below it organisms were found as cocci, single and in pairs, in transition stages towards rod formation, as single and jointed rods, and as elongated single rods. Many of the rods were actively motile.

The compact scum of two days' growth was sufficiently resistant to be removed in an unbroken sheet. When disturbed by the needle it fell to the bottom of the glass. It was found to contain all the forms found in the twenty-four hours' growth, and in addition long unbroken rods in transition stages towards the formation of chains of spores.

Spores were also found lying beside the empty and partially empty sheaths from which they had been discharged. Groups of single spores and pairs, identical in size and appearance with those which had come to maturity in the sheaths, were found mixed up with rods in all phases of development.

As no individual coccus or rod was kept under continuous observation, the process of growth can only be inferred by comparing the

various forms with each other, and thus tracing the successive stages in the development.

Examples of these different stages were drawn (Plate 6), and with the assistance of the figures I shall endeavour to describe what I believe to be the order of succession.

The first stage is undoubtedly the production of a pair from a single coccus. The individuals of the pair were sometimes found so closely associated that there was no independent movement in each member, in some a distinct movement of each could be observed, whilst in others the union was so loose that there was a perceptible distance between them, and they oscillated round each other, connected undoubtedly by a band of union which with the microscope I employed was not distinctly visible.

The next stage I take to be that in which the whole body is wedge-shaped, the round brightly refractive coccus being found in the thick end of the wedge. Another phase which is probably the successor of the preceding one, is the appearance of a canoe-shaped figure with the bright coccus in the centre. In one of these canoe-shaped bodies Mr. Knowsley Thornton and myself observed two of the bright refractive bodies in active oscillation in the centre of the canoe; one and then two being successively visible according to their relative position. The canoe-shaped envelope itself was motionless (the preparation was a permanent one sealed in diluted Goadby's solution), and Mr. Thornton was able to draw it with the camera. (See fig. 2, *a*, *b*.)

Other appearances connected with the early stage of development, and probably following the wedge and canoe-shaped figures, show the organism developed into a staff-shaped body, containing two elements of very different refractive power. The coccus element is still distinct and is brightly refractive, the other element is very slightly refractive and is seen as a dull shade, with however perfectly distinct outlines.

The latter element it may be convenient to term protoplasm, using the word merely to express the idea of an element which is distinct from the coccus and the sheath. The relative positions of the coccus or cocci and the protoplasm are various.

The coccus may be at one end of the rod, two cocci may be in the centre close together with a prolongation of protoplasm on either side, or a central rod of protoplasm may have a coccus at either end. (Fig. 2.)

In the next stage we have the formation of the rods characteristic of bacteria. The distinction between the coccus and the protoplasm becomes lost, although transitions are found in which faint differences of refraction still betray the two elements. At this stage, in the double flail-shaped rods, the one member sometimes refracts differently from the other, the development being evidently in a different stage. The numerous two-, three-, and four-jointed rods attached to each

other by a yielding elastic substance, which is very faintly refractive, complete the metamorphosis from the coccus to the rod.

The development of the rod appears to take place in two directions. In the one there is a formation of small segments whose fate it seems to be to be set free from each other (fig. 6); whilst in the other a formation of spores is introduced by a series of preliminary changes. The latter process begins by a lengthening out of the rod, which is frequently found of great comparative length. (These long rods are naturally liable to be broken in the preparation, but an idea of their length may be formed from fig 5, *a*.)

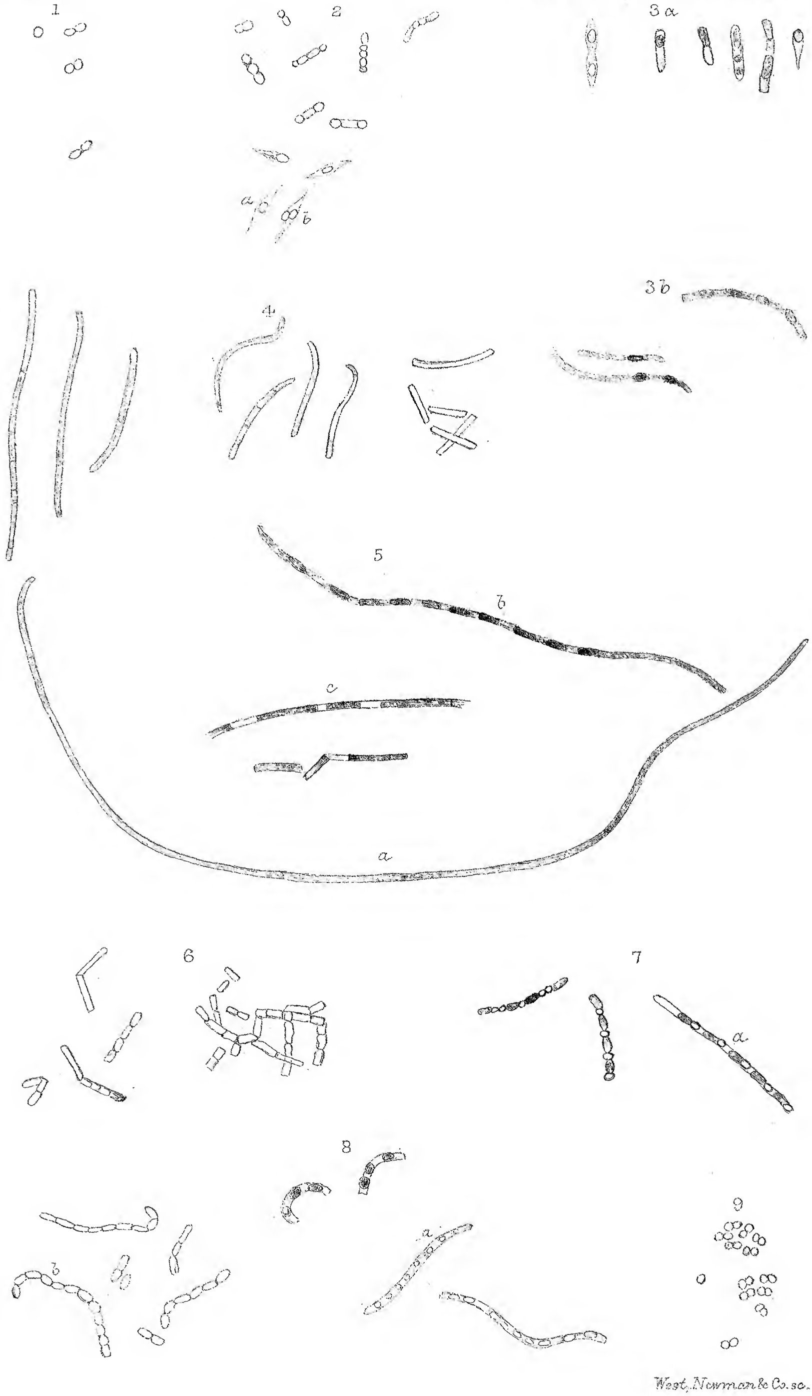
After the rods have attained a certain length, the protoplasm divides into separate portions in the tube (fig. 5, *b*, *c*). Minute refractive spheres then appear in the separate portions, but are also found occasionally in a long rod before the protoplasm has separated into segments (figs. 7, *a*, and 8, *a*). The delicate wall of the tube remains in the meanwhile entire.

The next stage is represented by tubes, in which the spores are so densely packed, that they almost touch (fig. 8, *b*), the wall of the tube being, however, still visible.

Two appearances, which were seen during the examination of fresh specimens, but were not noticed in the permanent preparations, have not been drawn. I several times observed tubes filled with spores, in which faint narrow lines of different refraction crossed the tube between the spores, giving the impression of the existence of a hyphen. I also several times observed tubes partially emptied of their spores, the escaped spores lying beside the empty tube, and resembling in every respect the spores still present in the portions of the tube which had not ruptured.

Amidst the mass of rods and tubes in all the different stages which are found in the scum, were found dense masses of micrococci. When they were set free by manipulation, and sufficiently isolated to be accurately observed, they were found singly and in pairs (fig. 9), and resembled in size and appearance, not only the spores which were observed in the ripe tubes, but those which were found in the meshes of the stocking.

Several cultivations were made in turnip infusion from the original stock and from various generations of the vitreous humour stock. No regular notes were taken of these cultivations, but I can state that the bacterium whilst it grows in turnip infusion grows less actively than in vitreous humour. It took from three to five days (at the same temperature at which the other cultivations were made) before a perceptible scum appeared on the surface of the fluid, and then the scum was not so thick as after a cultivation of half the time in vitreous humour. All the lengths of rod formation were found, but in none of the preparations examined did I find spores either in the long rods



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or free in the fluid. In many of the long rods segmentation of the protoplasm, by which rod-shaped masses of equal length were formed, was observed, the delicate tube wall being continued from one segment to the other unbroken. The observations were not sufficiently extended to determine whether the bacterium forms spores when cultivated in turnip infusion, but they suffice to show that if it does occur, it occurs much less actively than when the cultivation is in vitreous humour.

That the fœtid odour of the stocking is due to the development of the bacterium was shown by the characteristic fœtor being reproduced in the cultivation glasses, although the strength of the odour diminished in successive generations. The fluid of the fourth generation still smelt powerfully, and was at once recognised by several persons who had smelt the original piece of stocking; the fluid of the eighth generation still had the characteristic smell, but had it so feebly that although at once recognised by myself and the patient from whom the stocking had been obtained, it was not considered distinctive by a third person who had recognised the smell of the fourth generation. Mr. Lister, to whom I mentioned this fact, informs me, and authorises me to state, that he has made an analogous experience with the *Bacterium lactis.* This bacterium, after being cultivated in successive generations in urine, although it still retains its capacity to induce the lactic fermentation, possesses it in a less degree than when it has been grown in milk. The vitreous humour in a similar way would seem to be a less favourable medium for the *Bacterium fœtidum* (in so far as the production of the peculiar odour is concerned) than in the mixture of sweat and serum in which it develops in the stocking.

EXPLANATION OF THE PLATE.

[Figs. 1, 2, 4, 6, 7, 8, and 9 are camera drawings by Mr. Knowsley Thornton, made by the use of an excellent immersion objective by R. and J Beck, and I am much indebted to Mr. Thornton, not only for these careful and accurate drawings, but for valuable suggestions bearing on the subject of the paper. The magnifying power for these figures is 900 diameters.

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Fig. 1. The micrococcus, from the sock uncultivated. All the other figures are drawn from cultivated specimens.

Fig. 2. Micrococcus forms in development. *a* and *b* show two phases of the same object.

Fig. 3. *a.* Further stages in the development of the micrococcus; *b.*, examples of spore appearances in rods.

Fig. 4. Elongating rods.

Fig. 5. Elongated rods, three of them showing segmentation in the protoplasm.

Fig. 6. Segmented rods.

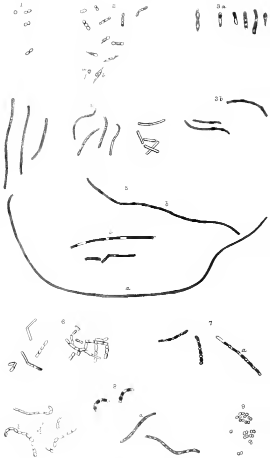
Fig. 7. Spores in the elongated rods; *a* is an example of a single spore formed at one end of each segment of protoplasm.

Fig. 8. Various phases of spore (coccus) formation in the tubes; *a* is an example of spheres in the protoplasm of an unsegmented rod; *b*, chains of spores (or cocci), in which remains of the tube, although hardly to be represented clearly in a drawing without exaggerating the appearance, are yet distinctly visible. In estimating the size of *b*, it is to be borne in mind that both the spores and the sheath make up the dimensions as they are shown.

Fig. 9. Micrococci or spores set free from scum, which is partly formed by rods in the various phases shown in the preceding figures.

III. "On the State of Fluids at their Critical Temperatures." By J. B. Hannay, F.R.S.E., F.C.S. Communicated by Professor G. G. Stokes, D.C.L., &c., Sec. R.S. Received May 24, 1880.

In carrying out the investigations which I commenced some years since upon the phenomena presented by the flow of different liquids through capillary tubes, the question as to what constitutes a liquid—that is in what way it differs from a gas, and how the great variance of the microrheometrical laws for the two fluids can be explained—again and again presented itself to me. Seeing that solids are soluble in gases as well as in liquids, one of the chief differences supposed to exist between the two states has disappeared; and I have been compelled to adopt as the only definition of a liquid, that it is a fluid which has cohesion. Professor James Thomson, F.R.S., has suggested to me the use of the term contractility, instead of cohesion, and this term admirably defines the liquid state, but as it suggests (in a distant way perhaps) a voluntary power, and is used in connexion with organised structures, I shall retain the term cohesion at present. We have then the two states of fluids, first, the gaseous, in which the *vis viva* or heat energy of the molecules has entirely overcome cohesion, or their mutual attraction, and they are prevented from grouping; and second, the liquid where the attractive power is greater than the *vis viva*, and the molecules are enabled to group themselves, but still are in sufficient motion to prevent the grouping from being permanent, hence we have cohesion, but no rigidity. We do not yet know that all solids are not also fluids, as many of them are known to flow, but this may be from other causes, but we know that the solid state is characterised by so much cohesion as to produce more or less rigidity. The most interesting point in the consideration of a liquid is that at which it approaches to the gaseous state, where its cohesion disappears, and we have what Dr. Andrews has termed the critical point, which is the termination of that property which distinguishes a liquid fluid from a gaseous fluid, or in other words the liquid be-



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